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# ABSTACT

## THE CORRELATION BETWEEN ACTUAL UNCUFFED ENDOTRACHEAL TUBE SIZE, THE DIAMETER OF THE DISTAL DIGIT OF THE LITTLE FINGER AND THE PENLINGTON FORMULA

By

Roy H. Fukuoka

May 1990

Fifty-three pediatric patients were involved in this study. The distal joint diameter of the little finger was measured and compaired with the overall diameter of the uncuffed endotracheal tube used during anesthesia. Also, the internal diameter of the uncuffed endotracheal tube used during anesthesia was compared to the calculated endotracheal tube size using Penlington's formula.

The correlation between uncuffed endotracheal tube size and both distal joint diameter and calculated tube size were both significant at the .01 level ( $r=.77$  versus  $.90$ ). The finger diameter was consistently larger than the overall diameter of the tube by a mean of 2.2 mm. Penlington's formula estimated the actual tube size in 49% of cases with the tendency

for calculated tube size to be smaller than the actual tube size by .5 cm (one tube size). Implication of the findings were discussed and suggestions for further research offered. *for calculation of tube size*



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THE CORRELATION BETWEEN  
ACTUAL UNCUFFED ENDOTRACHEAL  
TUBE SIZE, THE DIAMETER OF THE  
DISTAL DIGIT OF THE LITTLE FINGER  
AND THE PENLINGTON FORMULA

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Master of Science

By Roy H. Fukuoka  
BSN, University of Hawaii, 1980  
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## Chapter 1

### Introduction

In pediatric anesthesia, maintaining an adequate airway is usually the most important and most difficult procedure from induction of anesthesia to recovery from anesthesia. Prior to 1940 endotracheal intubation of infants and children was considered too dangerous and traumatizing. Since then, the view has changed and approximately 60 to 75% of pediatric patients undergo endotracheal intubation in pediatric centers (Smith, 1980).

Successful intubation with the appropriate size endotracheal tube is more difficult in children than adults. Children between the ages of one and eight years usually require tubes ranging from an internal diameter of three to seven millimeters (Gregory, 1989). In contrast, adults can be intubated using tubes with internal diameters of seven to eight-point-five millimeters (mm). Also, there are significant anatomical differences between the child and adult that explain why the intubation of a child is a more complicated process than the intubation of an adult. The head and tongue of infants and small children are proportionately larger than adults, predisposing

to airway obstruction with relaxation of muscle tone. In the infant, the larynx is cephaled, anterior, and located between the third and fourth cervical body as opposed to the fourth and fifth cervical body in the adult (Levine, 1980). The epiglottis of the infant is longer, stiffer, and "U" shaped angling backwards at about a 45 degree angle from the anterior pharyngeal wall. The adult's epiglottis is more flexible and tends to lie closer to the base of the tongue (Eckenhoff, 1951). Visualization of the child's anterior slanting vocal cords is more difficult (Barash, 1989). The infant's laryngeal structures resemble a funnel with the narrowest portion of the airway being the cricoid ring (Finucane and Santora, 1988). In contrast, the narrowest portion of the adult's airway is at the glottis, with the rest of the trachea being more or less equal in diameter. Thus, in an infant, the endotracheal tube can pass through the vocal cords yet be too large to fit through the cricoid ring. The trachea of a newborn infant is three to four millimeters in diameter (Donaldson and Tompsett, 1952) and approximately five to nine centimeters in length (Mattila et al, 1971) as compared to 10 to 14 mm in diameter and 12 to 14 centimeters (cm) in length in the adult (Miller, 1986). The

diameter of the airway has important implications on air flow rate in the trachea and is a significant consideration when intubating infants and children.

Although routine in adults, cuffed endotracheal tubes are usually not used for intubation of children less than six years old (Finucane and Santora, 1988). The use of a cuffed endotracheal tube increases the external diameter of the endotracheal tube, necessitating the use of a smaller endotracheal tube with a smaller interior diameter. In infants and young children, the smaller interior diameter greatly increases the airway resistance and work of breathing. Endotracheal tubes currently used, are manufactured primarily from polyvinyl chloride. The use of polyvinyl chloride allows the walls to be thinner than previous rubber tubes, thus maximizing the internal diameter and air flow.

Endotracheal tubes are sized according to three systems. The oldest method uses the Magill sizing system which was replaced by the French system that utilizes the circumference of the tube as the basis of measurement. Both the Magill and French system are not currently used. The system presently utilized standardizes tubes according to the internal diameter of the endotracheal tube in millimeters. This method

directs attention to the importance of the size of air passage that the tube provides. It also standardizes and compensates for variations in endotracheal wall thickness resulting from differences in various manufacturing processes.

A uncuffed endotracheal tube that inserts easily into the trachea but yet allows a small amount of gas leak of 15 to 20 cm of water is generally considered to be the appropriate size endotracheal tube in infants and children (Gregory, 1989; Miller, 1986). Measuring the gas leak is accomplished by manually deflating the reservoir bag and monitoring the approximate peak pressure at which the leak occurs. An alternative method is to slowly inflate the reservoir bag until a leak is audible. The pressure required to cause the tracheal mucosa to become separated from the tube approximates the lateral wall pressure. A tube that does not provide for a gas leak may induce trauma due to excessive pressure on the tracheal wall and lead to potentially fatal subglottic edema. Too small a tube increases airway resistance, the work of breathing, contamination of the operating room environment due to excess gas leakage and increases the risk of aspiration.

Various methods have been developed to aid in

determining the correct size endotracheal tube.

Many clinicians have developed tables and formulas based on their clinical experiences in selection of the appropriate tube size using parameters such as age, weight, height and body surface area (Slater et al, 1954; Hallowel, 1962; Keep and Manford, 1974; and Chodoff and Helrich; 1967). Results of these studies show a considerable overlap among the parameters, and the prediction of the appropriate endotracheal tube size is never made with certainty. Reasons for the variations can be attributed to three main factors: anatomical differences in laryngeal dimensions, the degree of muscle relaxation and the skill of the anesthetist (Slater et. al. 1955).

Two popular techniques that provide a rough guide in selecting the correct external diameter of endotracheal tube sizes in children is using the diameter of the distal joint of the little finger and the size of the lumen of the external nares (Smith, 1980). These two techniques are commonly used but have not been formally evaluated according to Gregory (1989). The review of literature revealed four references to this relationship, but no research studies to support or document this correlation (Davenport, 1982; Gregory, 1989; Miller, 1986; and

Smith; 1980). Although no formal evaluation has been accomplished, it seems logical that there should be a correlation between the growth rates of the cricoid cartilage and the distal joint of the little finger.

#### Problem Statement

Intubation of pediatric patients is considered routine in present day anesthetic practice. The importance of selecting the correct endotracheal tube is paramount in order to prevent potentially fatal complications and is always a challenge for the nurse anesthetist who works with pediatric patient. Various charts and formulas have been developed to provide a rough guideline in assisting in selection of the appropriate tube size. Due to variations in growth rates of children within the same age group, selection of the most appropriate size tube with absolute accuracy is difficult.

According to Smith (1980), it is commonly known that a correlation exists between the correct endotracheal tube size and the diameter of the distal joint of the little finger. He further states that formal research has not evaluated this correlation. Davenport (1982) and Gregory (1983) simply state that a correlation exists between the little finger and

tube size. Miller (1986) states that height of the distal phalanx approximates the external diameter of the appropriate endotracheal tube in 85 to 90% of pediatric patients, but reference for the data is not provided.

#### Purpose

The purpose of this study is to examine the relationship between the diameter of the appropriate sized uncuffed endotracheal tube used as evidenced by the adequate leak pressure and the diameter of the distal joint of the little finger for a pediatric population undergoing surgery. The diameter of the distal joint of the little finger will also be compared to the formulas  $4.5 + \text{age}/4$  for children older than six and a half years and  $3.5 + \text{age}/3$  for children less than six and a half years old. These formulas are commonly used as a guide in the selection of the appropriate sized tube.

#### Hypothesis

The first hypothesis is that there is a positive correlaton between the diameter of the distal joint of the little finger in a pediatric patient and the pediatric uncuffed endotracheal tube size.

The second hypothesis is that the diameter of

the distal joint of the little finger will predict the uncuffed endotracheal tube size more accurately than the formula  $4.5 + \text{age (years)}/4$  for children older than six and a half years and  $3.5 + \text{age (years)}/3$  for children less than six and a half years old.

### Theoretical Framework

The internal diameter of the endotracheal tube has a direct relationship to air flow resistance. Laminar flow through a rigid, smooth bore tube (endotracheal tube) follows the Hagen-Poiseuille's law. According to Poiseuille's law, the resistance to air flow in the airway is directly proportional to the viscosity of the gas, flow rate, length of the airway, and inversely proportional to the fourth power of the radius (Fletcher and Gluck, 1984) using the formula:

$$R = \frac{8nl}{r^4}$$

$n$  = viscosity of fluid

$l$  = length of airway

$r$  = radius of tube

The radius of the airway has a significant impact on the selection of the correct endotracheal tube size. A decrease in the diameter of the airway has

a great effect on airway resistance and work of breathing, especially in the pediatric patient. For example, if an endotracheal tube decreases the diameter of the trachea of a neonate by one millimeter, circumferentially the tracheal diameter is decreased by approximately 50% (four millimeters to two millimeters). The decrease in the diameter increases airway resistance 16 times if all other factors are kept constant. In the adult, the effect of increasing airway resistance is far less due to the much larger diameter of the adult's trachea. In the child, the effect of the diameter has such a significant impact on airway resistance that the largest uncuffed endotracheal tube that will pass through the cricoid ring and yet allow a gas leak of 15 to 20 cm of water is used as the criteria for selecting the appropriate size tube (Miller 1986). A tube that is too small causes an excessive air leak, increases the work of resistance, and increase the risk of aspiration. A larger than necessary tube might not pass through the cricoid ring or much worse, traumatize the mucosal tissue leading to subglottic or glottic edema with resultant respiratory compromise.

### Operational Definitions

For the purposes of this study the following terms are defined:

#### Appropriate Sized Uncuffed Endotracheal Tube

A endotracheal tube that fits easily through the cricoid membrane, yet allows a gas leak of between 15 to 20 cm of water as measured via a spirometer gauge. This gauge is standard equipment on the anesthesia machine.

#### ASA Classification

The American Society of Anesthesiologist classification of the potential risk of patients undergoing anesthesia. The classification system ranges from one to five progressively increasing in risk of death. Class I patients are healthy patients without systemic disturbances. Class II patients have mild to moderate systemic disturbances. Class III patients possess severe systemic disturbances. Class IV patients have severe systemic disturbances that are life threatening, and class V patients are moribund with little chance of survival.

### Closing Volume

The lung volume at which the airways begin to close.

### Cricoid Cartilage

One of the cartilages in the larynx. It is composed of two parts: a inferior ring portion and a posterior plate portion. The ring portion is the only part of the larynx where the cartilage form a complete ring. The cricoid is the narrowest portion of the airway in the pediatric patient.

### Functional Residual Volume

The volume of residual gas left in the lung after normal expiration.

### Glottis

The opening between the vocal cords which marks the opening of the larynx.

### Induction

That period in which anesthetic drugs are administered, the airway secured, and the patient is induced into a adequate anesthetic state.

### Infant

A child from birth to two years of age.

### Internal Diameter (ID)

The diameter of the endotracheal tube measured within the lumen.

### Laryngoscopy

A process of visualizing the oropharynx with a laryngoscope in order to visualize the vocal cords and glottis.

### Leak Pressure

The inspiratory pressure needed to cause an audible escape of gas around the endotracheal tube.

### Neonate

A newborn infant up to four weeks old.

### Penlington's Formula

Children under six and a half years of age require a endotracheal tube size (internal diameter in millimeters) equal to  $3.5 + \text{age}/3$ . Children over six and a half years of age need a tube size equal to  $4.5 + \text{age}/4$ .

### Uncuffed Endotracheal Tube

An endotracheal tube used in pediatric anesthesia that does not possess a cuff that is inflated to seal the endotracheal tube within the trachea.

## Chapter 2

### Literature Review

#### Characteristics of Endotracheal Tube

Uncuffed endotracheal tubes are supplied in a variety of materials, sizes and designs. The ideal tube should have the following characteristics: its internal diameter should be the largest possible within design limitations to allow adequate air exchange and passage of a suction catheter, the walls should be strong enough to prevent kinking, the tube should be soft and composed of nonirritating materials to prevent trauma to the tissue, and when sterilized, be free of the chemical cleaning agent.

The earliest tubes of the eighteenth century were constructed of metal (Stetson and Guess, 1970). Macewen described the first use of a flexible tube in 1880 (Guess and Stetson, 1968). In 1945, Cole developed a tube specifically for pediatric use. The tube was tapered and designed such that the terminal portion would pass through the vocal cords and the shoulder of the wide portion would seat on the vocal cords. A problem noted with this tube was the restricted vision of the terminal portion during intubation and trauma to the vocal cords (Branstater,

1969). Plastic tubes were introduced in 1949 (Dwyer, 1949). Currently the endotracheal tube of choice for most pediatric applications is the Magill uniform-bore tube composed of polyvinyl chloride. It has the advantages of a uniform diameter, pliability, relatively kink resistance, and is nontoxic to the tissue.

The development of the uniform bore endotracheal tube is the result of concern over increased work of breathing during spontaneous respiration and air flow resistance. Concerns over the air resistance and subglottic edema mandate that careful consideration should be given to the selection of the appropriate size tube.

#### Size Selection

The ability to successfully intubate the pediatric patient depends on being able to select an endotracheal tube of optimal diameter that fits through the cricoid ring. Intubation of children is made difficult by the varying growth rates that occur normally within the trachea. Tracheal measurements have been done in order to provide some standardization in tracheal sizes.

Postmortem autopsies of children (Engel, 1962;

Butz, 1968) have provided tracheal measurements, but these results must be viewed cautiously due to the gross discrepancy between autopsy measurements and actual measurements of the infant's trachea (Fearon and Whalen, 1967). Radiographic studies of 350 neonatal tracheas by Donaldson and Tompsett (1952) showed tracheal diameters ranging from one to seven millimeters between the fifth cervical and third thoracic vertebra. Keep and Manford (1967) used graduated Portex laryngeal sounds to directly measure the diameter of the trachea in 452 patients from six months to 16 years old. They found considerable overlap between age, height, and weight correlations and endotracheal tube size. For example, these researchers noted that an endotracheal tube with the internal diameter of five-point-five millimeters could be used with children in any of the following instances: in ages ranging from three to six years, with weights from 15-20 kilograms, and heights from 104-114 cm. The variations between tube sizes expected according to formulas and sizes of tubes actually found to be the best fit are also documented in studies by Chodoff and Helrich (1967) and Mostafa (1976). Both these studies document the wide variations in tracheal sizes that occur in the normal pediatric

population.

Besides normal variations in tracheal sizes, other factors also influence tracheal diameter. For example, the tracheal diameter changes, dilating during inspiration, narrowing during expiration and decreasing the diameter as much as 50% when crying or struggling (Fearon and Whaler, 1967; Whittenborg, 1967). Another factor that must be considered is the position of the head and neuromuscular blockade. Finholt et al (1985) studied factors that affected "leak" pressures in 80 surgical patients intubated with uncuffed tracheal tubes. He found that leak pressure increased with complete paralysis and turning the head from a neutral position to one side. The leak pressure was defined as the inspiratory pressure needed to cause an audible gas leak.

An important consideration in selecting the correct tracheal tube is prevention of aspiration. Browning and Graves (1983) cited an alarming 77% dye positive tracheal aspiration in their patients who were intubated with uncuffed endotracheal tubes. More recently Goitein et al (1984) found evidence of aspiration in only 16% of their patients. In both studies dye was placed in the back of the tongue, and the trachea was suctioned at varying intervals.

Goiten attributes the lower incidence of dye aspirate in his study compared to the Browning and Graves data as the result of his using a lower volume and concentration of dye. He further stresses the efficacy of noncuffed endotracheal tubes in preventing clinically significant aspiration and the importance of selecting the correct tube size.

Historically, the earliest attempts at selecting the correct tracheal tubes were based on clinical experimentation. From these experiences, various charts and formulas were developed. Slater et al (1955) studied endotracheal tube sizes used over a three year period in order to facilitate the selection of the proper tube size according to age. He used the largest tube that would fit through the larynx without resistance. His chart reflected the considerable variation in tube sizes that were required. The major point emphasized in his study was the need to have tubes available in variety of sizes. Other authors (Keep and Manford, 1974; and Hallowell, 1962) also devised charts, each differing slightly in recommended tube sizes according to age.

The first formula developed to calculate the correct tube size was Cole's formula which is not currently used because it is based on the French system

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of measurement. A popular formula now used is Penlington's formula (1974) which is: 1) for children under six and a half years old, the tube size in internal diameter is equal to  $\text{age (years)} / 3 + 3.5$ , 2) for children older than six and a half years old, the internal diameter of the tube is equal to  $\text{age (years)} / 4 + 4.5$ . The formula serves as a rough guideline and was based on the results of Keep and Manford's (1974) study. These researchers studied 452 patients between the ages of six months and 16 years. The correlations between endotracheal tube size and age, height, and weight were assessed. The greatest correlation occurred between height and least with weight. Due to the difficulty in using the height correlation formula ( $\text{tube size (millimeter)} = \text{height (centimeter)} \times 0.045 + 0.8$ ), clinicians opted to use the formula that utilizes age (Penlington, 1974). From Keep and Manford's results, Penlington noted that the correlation between endotracheal tube size and age could be separated into two statistically significant groups one for greater than six and one-half years of age and the other for less than this age group.

In order to further simplify the formula, Levin (1980) proposed a single pediatric formula: internal

diameter of the endotracheal tube is equal to age (years)/ 4 + 4.5. Other authors, including Finucane and Santora (1988), also cite this formula as a guideline in tube selection. The problem with such simplification is the correlation between the expected tube size and observed tube size become less. In fact, studies by Lee et al (1980) and Mostafa (1976) also determined that large variations occurred between the calculated and observed tube sizes as determined by leak pressure. Lee and his team, using Levine's simplified formula, found that 30% of his patients had an airway leak pressure that exceeded 40 cm of water; and, in 23%, the leak pressure occurred at less than 20 cm of water. Mostafa found that within each age group, 15 percent of the pediatric patients required a tube one size smaller, one percent two sizes smaller (both indicating a high leak pressure) and in 11 percent, one size larger (indicating a low leak pressure) than predicted for age using Levin's formula.

Despite the variations between the estimated and observed tube sizes, most experts recommend the use of age in calculating tube sizes (Penlington, 1974; Smith, 1980; Steward, 1985; Fincucane and Santora, 1988; and Gregory, 1989). Using age (versus

weight or height) in calculations, especially in the clinical arena, greatly simplifies time required for calculations as well as providing an accurate means of predicting endotracheal tube size. Another method of determining the correct size endotracheal tube that does not depend on age is to lay the child's finger on a flat surface and compare the external diameter of the tube and distal joint of the little finger. This measurement provides a rough guideline and is cited by several authors (Smith, 1980; Davenport, 1982; Miller, 1986; and Gregory 1989) as a useful gauge to determine endotracheal tube size. Miller further states that approximately 10 to 15% of children may still require an endotracheal tube one size smaller or larger, although no documentation was mentioned. In fact, no reference was mentioned by any of the authors as to the source of the data relating tube size with finger diameter. It is apparent that all of the nurse anesthetist and anesthesiologist that I have interviewed are aware of this relationship.

Very few of these clinicians use this method in determining tube size, but the few that do state that a relationship exists.

### Summary

In spite of the work that has been done, determining the exact size of endotracheal tube needed for children undergoing anesthesia is still not possible prior to actual intubation. Formulas have been developed, however, they serve only as guides. This is especially true in children where individual growth rates vary greatly. For this reason, all authors and clinicians recommend that various sizes of tubes be laid out in preparation should the first tube not fit correctly. The final selection of the correct tube depends on the skill of the anesthetist in being able to predict the consequences of position, neuromuscular blockade and anatomic factors on airway leak pressure. Although mention is made relating the diameter of the distal digit of the little finger with the appropriate endotracheal tube size, no formal evaluation of this relationship can be found.

### Chapter 3

#### Methodology

The purpose of this study is to determine the relationship between two measures in establishing the appropriate sized endotracheal tube to use for a pediatric population undergoing anesthesia. One method will use the Penlington formula for calculating tube size according to age. The other method will be a measurement of the diameter of the distal joint of the little finger.

#### Setting

This study was conducted in several large hospitals in Southern California over a two month period.

#### Subjects

The study population consisted of 53 children, from ages two months to 8 years old, undergoing general surgery. The rapid growth that occurs during the first two months makes the formula invalid during the neonatal period (Gregory, 1989), therefore this group of pediatric patients were not included in the study. Also, uncuffed pediatric tubes are rarely

used in children greater than eight years old, therefore children older than eight were excluded. All of these subjects required the use of an uncuffed endotracheal tube and would routinely be intubated for their required operation. The children were ASA I or II. Patients who had the following anomalies or pathologies that might have an impact on endotracheal or little finger size were excluded from this study:

1. Tracheal deformities.
2. Trauma to trachea or upper respiratory tree.
3. Tumors or growths in neck.
4. Subglottic stenosis.
5. Arthritis.

The selection of subjects was accomplished according to the hospital operating room schedule and purposive sampling was utilized. Each child was assigned a number and confidentiality was preserved.

#### Methods and Procedures

Upon notification that oral endotracheal intubation would be the airway of choice, the following data was collected from the hospital record:

1. age (months)
2. weight (kilograms)

- 3. diagnosis
- 4. type of procedure
- 5. ASA
- 6. significant history related to the airway

The researcher collected all data in an attempt to reduce measurement errors that could result if data was collected by more than one individual. In an attempt to estimate the amount of researcher error associated with caliper measurements, five pediatric volunteers were selected and distal joint measurements were taken on the ring and little finger for a total of 20 measurements. The measurements were repeated two days later to eliminate recall of previous data with an average of .13 mm of difference in all measurements. The researcher was not aware of the original measurements when repeat measurements were taken. This amount of error was not significant as endotracheal tubes are supplied in incremental sizes of .5 cm. The instrument used in measuring was a RCBS caliper accurate to .1 mm.

The estimated tube size was calculated according to Penlington's formula before induction of anesthesia. The anterior to posterior diameter of the distal digit of the little finger was measured with the caliper to the nearest .1 mm and recorded on a data sheet

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(Appendix A) either in the pre-operative holding area or following induction in the operating suite. Preliminary studies by the researcher showed a variance of as much as .5 mm between the measurements of the distal joint of the right and left little fingers on the same person. Therefore, the distal joints of both little fingers were measured to determine which finger might approximate endotracheal tube diameter to a better degree. The number of attempts at insertion of the tube were noted as well as the sizes of tubes used. The appropriate sized tube used provided a leak pressure within 15 to 20 cm of water. The leak pressure was measured by the researcher using a pressure gauge that was standard on the anesthesia machine. Calibration of this gauge is routinely done by the bioengineering department of the hospital.

#### Statistical Analysis

The correlation coefficient was computed between the endotracheal tube used and measurements of diameter of the distal digit of the little finger. In addition, the correlation coefficient was calculated between the actual endotracheal tube used and calculated tube size according to Penlington's formula. The level of significance was established at .01.

## Chapter 4

### Results

This study examined the relationship between uncuffed endotracheal tube diameter and its relationship to the external diameter of the distal joint of the little finger and the correlation between uncuffed endotracheal tube size and calculated tube size using Penlington's formula.

Fifty-three children were included in this study ranging in age from two months to seven years old. The mean and median age was three years old. Of the 53 children, 36 were male and 17 female. The majority of children were classified in the ASA I category with only seven classified as ASA II. There were no children in the ASA III, IV, or V classification. Most of the procedures were relatively minor procedures such as tonsillectomy/adenoidectomy, hernia repair, circumcision, or orchiopexy.

The diameter of the little fingers of both hands were measured either in the pre-operative holding area or after induction of the child. The data for the external diameter (or overall diameter) of the uncuffed endotracheal tubes was taken from data on the endotracheal tubes (Appendix B). The little finger

diameter measurements revealed the following information: the right little finger diameter was larger than the left little finger in 16 (62.3%) of the subjects, four subjects (7.5%) had little fingers of equal diameters, and 16 (30.2%) had left little finger diameters larger than the right little finger. Since the left little finger was smaller in the majority of children, it's diameter was used in comparing the relationship to the external diameter of the endotracheal tube.

The diameter of the left little finger was equal to the diameter of the endotracheal tube in only one case. Of the remaining 52 subjects, the diameter of the little finger was consistently larger than the external diameter of the tube used. The diameter of the distal digit on the little finger as compared to the diameter of the endotracheal tube ranged from the same diameter (one subject) to 3.8 mm larger. The mean difference was 2.2 mm larger. The Pearson Product correlation between the left distal joint diameter and the external diameter of the endotracheal tube was .77 at the .01 critical value. The scatter plot of the results can be found in appendix C.

The analysis of data on the relationship between Penlington's formula and endotracheal tube size

revealed that the formula accurately predicted the endotracheal tube size used in 26 cases (49%). In 27 cases (51%) the calculated tube size differed from the actual tube size used. In 17 (66%) of these 27 cases, the calculated tube size was smaller than the actual tube used by one tube size (.5 cm). In one case (1.8%) the calculated tube size was smaller by one centimeter. In the remaining nine (33%) out of 27 cases, the calculated tube size was larger than the tube used by one tube size (.5 cm). The Pearson Product correlation was .90 at the .01 significance level. The scatter plot of the results can be found in appendix D.

## Chapter 5

### Discussion

The selection of the appropriate uncuffed endotracheal tube during pediatric anesthesia remains one of the most important and challenging tasks for the nurse anesthetist. During the intubation period, the child is either under deep anesthesia or paralyzed and the nurse anesthetist must visualize the vocal cords with the laryngoscope and insert the appropriate tube into the trachea. Since the oxygen reserve is decreased in the child (Gregory, 1989), the intubation process must proceed rapidly otherwise oxygen desaturation occurs quickly. Should the selected endotracheal tube be too large or small, it must be replaced in order to prevent potential complications. Therefore the selection of the correct tube is critical.

The results of this study indicate that there is a strong correlation between the diameter of the appropriate endotracheal tube compared with both the diameter of the distal digit of the little finger and Penlington's formula. At the .01 significance level, both correlations were significant with Penlington's formula being more significant ( $r=.90$

versus .77). A possible explanation for this greater correlation might be due to the statistical derivation of Penlington's formula based from data provided by Keep and Manfords study (1974) of 452 pediatric patients.

The results of the study correlating the diameter of the distal joint of the little finger with tube size differ markedly from the data provided by Miller (1986). He states that approximately 10 to 15% of the children would require tube sizes one size larger or smaller, whereas the results from this study indicate that 98.2% of the sample subjects required a different tube size. The data also revealed that the finger diameters varied to a greater extent than endotracheal tube sizes. For example, within the three year old group of children, the little finger diameters ranged from 7.5 to 9.8 mm, whereas the external diameter for the endotracheal tubes were either 6.1 or 6.8 mm (4.5 and 5.0 ID). This supports the greater range in growth rates in fingers as compared to the trachea of the three year old child. Never the less, the use of the distal digit of the little finger can be used as a rough guide in the selection of the appropriate tube size with the understanding that the external diameter of the tube

will probably be smaller than the diameter of the distal joint of the left little finger by a mean of 2.2 mm.

A significantly more accurate method of predicting the correct tube size utilizes Penlington's formula. The results of the study indicate that selecting the correct tube size using this formula would be correct in 49% of cases. In the majority of cases the tube size was off by .5 cm, with the major difference being underestimating the correct tube size by one tube size (66%). A possible explanation for such a large difference could be the improved nutrition and possible greater growth rate of present day children as compared to the children in the Keep and Manford study (1974). A greater average growth rate in present day children would result in underestimating the correct tube size.

The high percentage of error involved in estimating tube size stresses the importance of having tube sizes of varying diameters in the event the selected tube should not fit. This also emphasizes the skill required of the nurse anesthetist in making the correct decision regarding tube size dependent on the age and size of the pediatric patient. Many methods are available to assist in the selection of the appropriate tube size including charts, formulas

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and the diameter of the distal joint of the little finger, but the final decision rests on the clinical aptitude of the nurse anesthetist.

#### Limitations and Implications for Further Research

The major limitation of this study was the limited sample size of 53 subjects. This number of children dispersed between the ages of two months and seven years limited the number of subjects within each age group. As an example, the number of children within the two, five, and six year old catagories numbered four. A larger sample size would have increased the statistical significance for this study.

Further research should be directed towards obtaining a larger sample size and analyzing the data in hopes of perhaps devising a formula that more accurately reflects the estimation of the correct tube size.

# Data Collection Tool

Pt. #						
Age						
Sex						
Wt. (Kg.)						
ASA						
Medical History						
Operation						
Dia. Distal Joint Little Finger L/R (mm)						
I.D. of Ett.						
Ext. Dia. Ett.						
# of attempts						
Calc. Ett. Size Less $6\frac{1}{2}$ yr.= $3.5 + \text{age}/3$ greater $6\frac{1}{2}$ = $4.5 + \text{age}/4$						

Appendix A

Internal Diameter (ID)

External Diameter(OD)

2.5

3.5

3.0

4.1

3.5

4.8

4.0

5.4

4.5

6.1

5.0

6.8

5.5

7.5

6.0

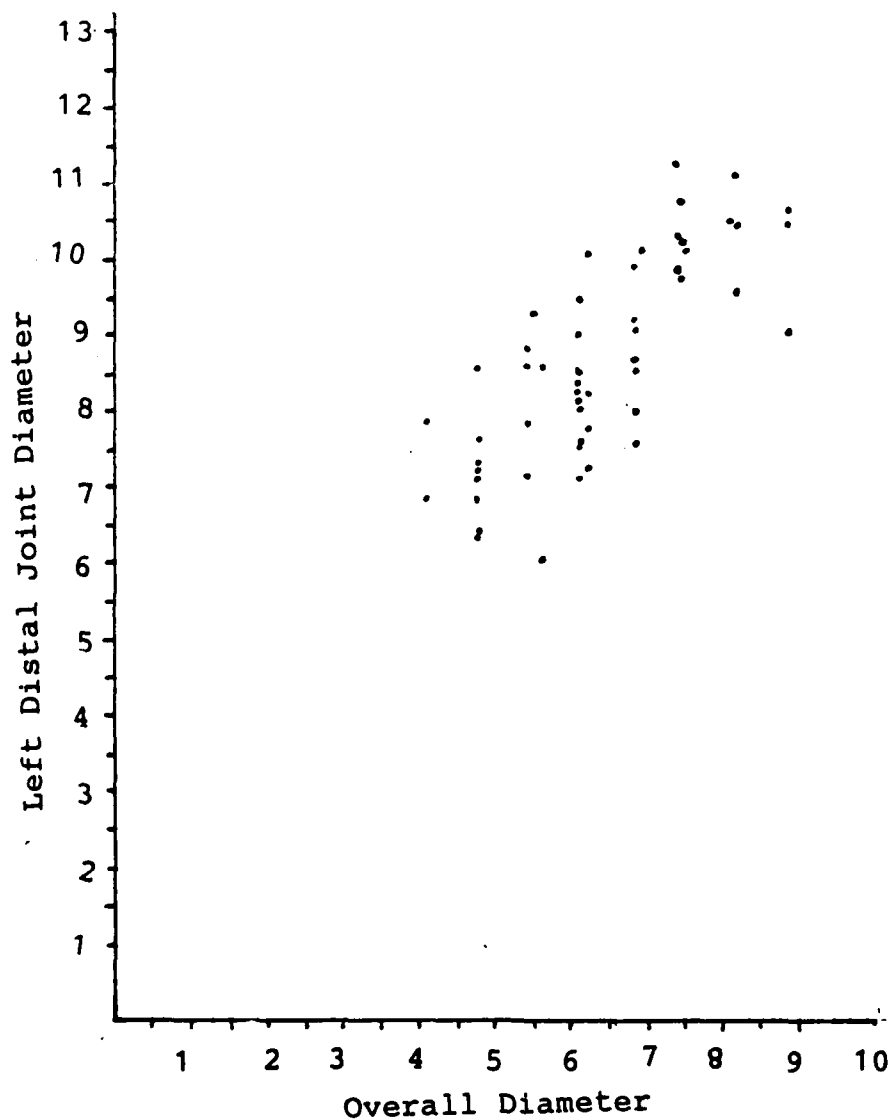
8.2

6.5

8.9

Comparison of Internal and External Diameters of  
Uncuffed Endotracheal Tubes

Appendix B



Scatter Plot of Left Distal Joint Diameter (mm) of the Little Finger Versus Overall Diameter (mm) of Uncuffed Endotracheal Tube

Appendix C



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